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ABSTRACT

Children's serial motor skill acquisition was studied within a neo-Piagetian framework. High and low M-processors (a designation of a child's ability to produce problem solutions) performed on a curvilinear repositioning task. A primacy-recency effect was evidenced for both groups on the age-related task, while a recency effect occurred for only the high M-processors on the task one stage beyond the developmental processing capacity of the subjects. High M-processors were more accurate and less variable than low M-processors. Although low M-processors performed better on the more complex task than on the simpler one, their performance never exceeded that of the high M-processors. Implications of these results for future research are discussed. (Author)

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A NEO-PIAGETIAN INVESTIGATION OF THE SERIAL POSITION EFFECT IN CHILDREN'S MOTOR LEARNING

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Children's serial motor skill acquisition was studied within a neo-Piagetian framework. High and low M-processors performed on a curvilinear repositioning task. A primacy-recency effect was evidenced for both groups on the age-related task, while a recency effect occurred for only the high M-processors on the task one stage beyond the developmental processing capacity of the subjects. High M-processors were more accurate and less variable than low M-processors. Although low M-processors performed better on the more complex task than on the simpler one, their performance never exceeded that of the high M-processors. Implications of these results for future research were discussed.

During serial task learning, a person is required to learn items in a sequential order. In verbal learning, subjects evidence a "bow-shaped" curve whose shape is indicative of the probability of recalling a given item in a sequence, depending on the location of that item in the list. Usually, items presented either early or late in learning are recalled most accurately, and those items presented during the middle of the list are recalled with the greatest number of errors. Regardless of the length of the list, assuming it is sufficiently long to produce a bow-shaped error curve, relative errors at each presentation position remain the same (McCrary & Hunter, 1953) These results are mainly due to the amount of interference associated with the position of each item in the list (cf. Glanzer, 1972).

The serial learning curve has also been used to provide evidence for two separate storage and retrieval processes during performance. According to this idea, earlier presented items were retrieved from long-term store, while later presented items were retrieved from the short-term and long-term stores, with the short-term store being dominant The middle items in a list were retrieved with the most errors because these items were being removed from the short-term store, and had not yet been completely transferred to the long-term store (Glanzer, 1972; Glanzer & Koppenaal, 1977) Although other explanations of serial learning of verbal materials exist (Harcum, 1975), the Glanzer description of the effect would seem to be the most applicable to motor learning It is unknown, therefore, why this account of serial skill acquisition has not been investigated more thoroughly with motor tasks.

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In motor learning, proactive interference has often been cited as the reason for serial position effects (Magill, 1976) The interfering effect of previous items on the recall of subsequent items in a movement sequence can readily account for the superior recall of initial items, while the latter items are recalled because they are still active in memory and not subject to extensive interference effects Items in the middle of a sequence are proactively and retroactively interfered with, so they are not fully encoded, and they are recalled poorly Although this explanation is compatible with the previous one of distinct storage processes leading to differential performances, the two interpretations of serial skill acquisition have not been used conjunctively

It is difficult to explain serial motor skill acquisition because equivocal results have been reported (Cratty, 1960, Magill, 1976, Wrisberg, 1975, Zaichkowsky, 1974) Wrisberg found serial-position effects while the other researchers did not These disparate findings seem to be explained best by the differences in methodology, such as varying task demands and subject populations If adult learning is truly a recombination of previously learned skills (Schmidt, 1975), then it is necessary to employ a theory to early motor skill acquisition which provides a developmental explanation of learning stages as well as a description of how children utilize information within each stage

Neo-Piagetian Theory

Pascual-Leone (1970) added a quantitative parameter to Piaget's (1952) theory of discontinuous cognitive stages to make functional the qualitative phenomena described by Piaget Neo-Piagetian theory (Pascual-Leone 1970 Pascual-Leone & Smith, 1969) was operationalized for research because it accounted for the orderly progression of processing ability through developmental stages it was descriptive of the within-stage variability (individual differences) in terms of problem-solving capabilities (i e high and low M-processors, which is a designation of a child's ability to produce problem solutions), and it was a framework in which the components of a task could be analyzed in order to determine how much information was inherent in each task Additionally, neo-Piagetian theory does not require a beginning competence level of cognitive development for its postulates to be tested, as it was designed to account for those developmental stages through which a child progresses The neo-Piagetian interpretation of learning would explain individual differences in children's behavior on both cognitive and psychomotor tasks thus making it more appropriate than other information-processing approaches for studying the serial-position effect in children's motor learning

The significance of this approach for children's motor learning is that the amount of information presented to a child can be quantified in terms of number of schemes (units of information) In a levels of processing approach (Craik & Lockhart, 1972), the variations in encoding instructions presented to subjects is difficult to quantify The different instructions only serve to provide an encoding strategy to the subject, and it is difficult to determine if the results are actually due to depth of processing (Craik & Lockhart, 1972), elaboration of encoding (Craik & Tulving 1975) or differential strategy usage Thus, the results of these studies are often clouded because the amount of task information varies in an unspecified manner while in neo-Piagetian investigations the amount of information is equal to a specified number of schemes

In neo-Piagetian theory the existence of a central computing space (M-space) is postulated This M-space is composed of a structural component (M_s space), which is the specific stage processing capacity and a functional component (M_f-space), which is that portion of the M_s-space a child utilizes at any particular moment Variations in the utilization of M_f-space have allowed experimenters to dichotomize children into groups of high and low M-processors Since the M_s-space is assumed to be equivalent for any child within a developmental stage it is the use of some portion of the available processing capacity which defines a child as either a high or low M-processor

Differences between high and low M-processors within a developmental stage would lead to the conclusion that information which is learned best is that information which the child

is capable of processing and retaining Any additional information would exceed the processing limits, and a decrement in later performance when compared to earlier performance may be expected. Therefore, a serial position effect can be explained within a neo-Piagetian framework in the following manner If subjects were low M-processors, a steady decline in motor performance would be expected as the number of response items to be recalled increased This is because the low M-processors generally process information in a less effective manner when compared to high M-processors at the same developmental stage (low M-processors use less functional M-space) Additional information would extend beyond the processing capacity limits of the child's system and cause an increase in performance errors (Zaichkowsky, 1974) Any recency effect would be due to a small number of later presented items remaining active in memory. High M-processors should produce a stronger primacy recency effect Since this group of children often use more of their M, space for processing than used by low M-processors, they are capable of generating strategies to facilitate the performance of tasks that may appear to exceed their processing capacity This would result in a strong primacy effect Motor responses in the middle positions would receive less processing attention because they are presented at a time when the initial items are being processed, and performance should decrease in a manner similar to the low M processing group for middle-position items The recency effect would then be evidenced within the high M processing group due to the processing strategies they would employ The early response items become learned and stored in memory, while the middle response items are not rehearsed because memory capacity is unavailable due to the processing of the early response items Finally, the later response items are presented and they can be processed and learned similarly to the initial items because more of the processing capacity is available due to encoding of early presented information

Within the parameters of neo-Piagetian theory, an appropriate motor task was designed to test the possibility of a bowed serial position curve occurring during the acquisition and recall of a series of positioning responses Specifically, both high and low M processors would show a retention curve related to ordinal position of the response items Further hypotheses which were tested were as follows (a) high M-processors would evidence greater accuracy and less variability in their performances than the low M processors, (b) high M processors would achieve more correct responses on the five-scheme task than the low M processors, while no difference would exist between groups for correct responses on performance of the four scheme task.

Method

Subjects. Males, aged 9 and 10 yr (late concrete, e + 4) from the fourth grade of two Tallahassee public schools, served as subjects Hand preference was not a criterion for selection (Gerson & Thomas, 1977) Twenty subjects participated in the final experiment.

Apparatus. The Figural Intersection Test (FIT), described elsewhere (Thomas & Bender, 1977), was used initially to determine subjects for testing on the criterion task The FIT is a paper-and-pencil test which determines a child's cognitive problem solving ability The test is composed of a series of overlapping geometric shapes from which the subject must determine the location of the intersection space of the test figures Since the FIT is a measure of cognitive problem-solving ability, other factors, such as IQ, race, and socioeconomic status may be artifacts affecting performance on this test However, de Avila and Hayassey (Note 1) have shown that these factors have no effect on performance related to high and low M processors Therefore, it was concluded that the FIT is a measure of cognitive problem solving ability, and thus, it was used to dichotomize the subjects into high and low M processing groups

A total of 66 children were administered the FIT Based on a sample mean score of 44 57 (SD = 28 20), 10 high and 10 low M-processors were selected High M processors were defined as those children scoring more than 1 SD above the age group sample mean and low M-processors were defined as children scoring more than 1 SD below the mean The mean

score for the high M-processing group on the FIT was 83 40 (SD - 7 81), and the mean score for the low M-processing group was 9 40 (SD=3 81)

The criterion task was a curvilinear positioning task which has been described elsewhere (Gerson & Thomas, 1977, Thomas & Bender, 1977) It consisted of a metal pointer which rotated freely to transcribe an arc of 217°

Procedure A task analysis of the criterion response per trial was performed as suggested by Mitchell (Note 2) A trial consisted of the subject moving the pointer to a randomly chosen experimenter defined stop These stops differed on each trial After a 1 sec pause at the stop, the subject returned the pointer to the start position The subject then moved the pointer to another stop, 30 greater than the first stop Following a 1 sec pause at the stop, the subject again returned the pointer to the start position This identical procedure was followed until the subject contacted four experimenter defined stops After contacting each of the four stops, the subject was then asked immediately by the experimenter to reposition the pointer mid-way between two of the location points with the stop pegs removed This constituted one complete trial The task analysis revealed this to be a four-scheme task, which was developmentally appropriate for the age of the subjects in the study The intertrial interval was 5 sec

Subjects were asked to reposition the pointer mid-way between two location points, rather than at a location point because of certain prescriptions within neo-Piagetian theory During a reproduction movement a child must activate the schemes for the two points chosen by the experimenter Those locations must be retrieved from memory It is the ability of the children to retrieve the appropriate cues for movement replication which defines high and low M-processing capability Furthermore the provision of two location cues should provide more information from which the subject either high or low M-processors, could produce a correct response

The task analysis was conducted by considering the response requirements the subject had to meet in order to formulate a correct response A correct response was a reproduction movement which the subject terminated between the two location points described by the experimenter An error was considered as a reproduction response which was not terminated between the chosen location points For the developmentally appropriate four scheme task, the child had to move to the four experimenter-defined location points This constituted the criterion phase of a trial in which the subject was kinesthetically informed of the four target locations in the sequence During the reproduction phase of a trial the subject had to reposition the pointer between two locations specified by the experimenter The subject was required to activate three schemes to produce the reproduction movement, a scheme corresponding to each of the two targets and one for controlling the movement to a point between those two targets Thus, the task analysis resulted in the repositioning phase of a trial being a three-scheme task

The fact that the repositioning task was only a three scheme task does not indicate that better performances will occur The M demand of a task is determined by the maximum number of schemes a subject must activate at any one time In this case, four figurative schemes must be activated before the subject is told where to reposition the pointer Although the M-demand of the task may appear to be reduced any variation in performance would be the result of different steps the child processor progresses through

Similar procedures were followed for the same subjects when a five-scheme task was used A task analysis revealed this task to be one scheme beyond the developmental stage of the subjects The task analysis procedure was identical to the four scheme task, and the repositioning response on the five scheme task also became a three scheme task in a manner similar to the way the demands of the four scheme task appeared to be reduced

With the apparatus placed directly in front of the subject at tabletop height, each subject, while seated in a chair, received 12 trials on the four scheme task and 16 trials on the five-scheme task so the number of reproduction movements to each position would be equally represented The only direct feedback available to the subject was kinesthetic Visual feedback was controlled by a curtain under which the child placed the hand which grasped the

handle of the curvilinear task. Auditory feedback was controlled by the almost frictionless movement of the pointer.

The order of task presentation was counterbalanced for each subject to negate any possible practice-effects (Gerson & Thomas, 1977). Additionally, the initial stop position on each task was chosen at random. The criterion repositioning responses were also counter balanced within each task to negate any possible order effects for each subject.

Results

To determine the effect of the presentation order on the sequential position of the repositioning response, a 2 x 3 (groups x positions) factorial analysis of variance was calculated for the total number correct responses on the four-scheme task. Significant main effects were evidenced for groups, $F(1,18) = 8.33$, $p < .01$, and positions, $F(2,18) = 4.80$, $p < .05$. A comparison of the mean scores for groups showed that high M processors displayed a greater percentage of correct responses (reproduction movements between the two chosen location points on each trial) than low M-processors (High = 74%, Low = 48%). A follow-up Newman-Keuls test on the position means was not sensitive enough to determine where the significant differences existed. However, an inspection of the position means for correct responses (1.8, 1.3, and 2.4, for the three positions, respectively) showed that performance was best when the criterion position to be recalled was presented as the midpoint of the last two location points in the four-scheme task (position 3), thus indicating the hypothesized trend in the data. This recency effect for both groups was further displayed by calculating and then plotting the percentage of total errors occurring at each position (McCrary & Hunter, 1953). This procedure would yield an accurate assessment of the relative difficulty of recall within a sequence, as depicted in Figure 1. In the graph, it is also shown that a primacy effect occurred for both groups. The curves were almost identical in shape, with the high M processors exhibiting superior performances at all three positions.

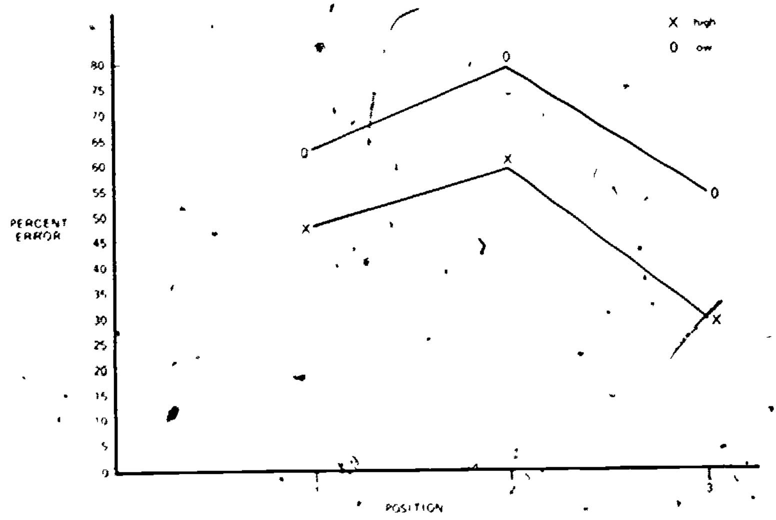

Fig. 1. Percent recall errors on the four-scheme task.

A 2 x 4 (groups x positions) factorial analysis of variance was performed on the total number of correct responses on the five-scheme task to determine a serial position effect. All effects were nonsignificant. Similar to the four-scheme task, the percentage of errors made at

each position on the five-scheme task was calculated and plotted (Figure 2). It is apparent that the trend was toward a recency effect in motor recall, but only for the high M-processors.

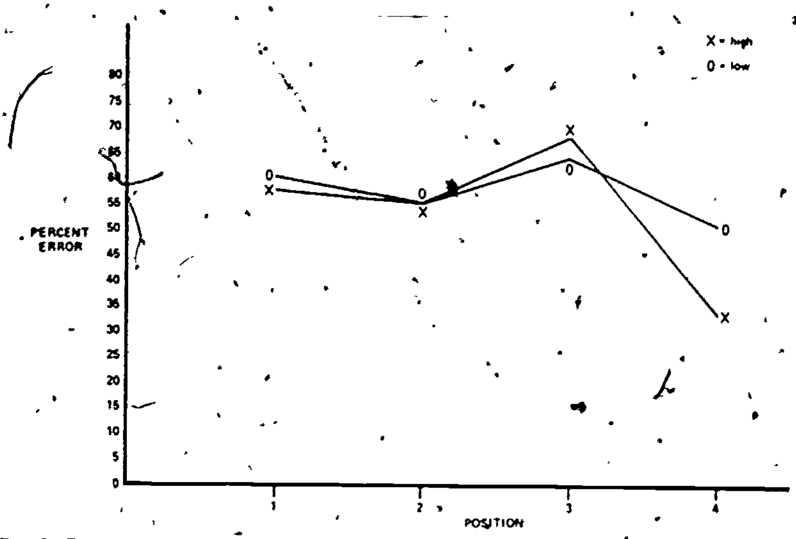

Fig. 2. Percent recall errors on the five-scheme task

The dependent variables of total correct responses, mean constant error, and mean variable error over all trials were analyzed with a 2 x 2 (groups x schemes) multivariate analysis of variance. The main effects for groups, $F(3,16) = 6.50$, $p < .05$, schemes, $F(3,16) = 3.63$, $p < .05$, and the group x scheme interaction were significant, $F(3,16) = 4.45$, $p < .05$.

Univariate analysis of variance techniques were performed as follow-ups on each dependent variable. It was found that correct responses yielded significant main effects for groups, $F(1,18) = 7.31$, $p < .05$, and for schemes, $F(1,18) = 7.31$, $p < .05$. The high M-processing group (mean = 7.10) exhibited a greater number of correct responses than the low M-processing group (mean = 5.50), and performance on the five-scheme task (mean = 7.10) yielded more correct responses than performance on the four scheme task (mean = 5.50).

Additionally, to counteract any possible practice effects which may be associated with the five-scheme task, the percentage of correct responses made in relation to the total number of responses was calculated, and an analysis of variance was performed on the correct responses for each task. The percentage for the five-scheme task (44%) was almost identical to the percentage for the four scheme task (46%). The analysis of variance revealed them not to be significantly different. Therefore, the difference in the mean number of correct responses was due to increased sampling of behavior on the five-scheme task, and not to any practice effects.

The univariate follow up on the variable error scores yielded a significant main effect for groups, $F(1,18) = 17.87$, $p < .01$. Inspection of the means showed that the high M-processing group (mean = 19.57°) exhibited less variability in their performance than the low M-processing group (mean = 28.39°). No other significant effects occurred with this measure.

The follow up analysis of the constant error variable yielded a significant scheme effect, $F(1,18) = 7.54$, $p < .05$, and a significant group x scheme interaction, $F(1,18) = 13.28$, $p < .01$. Inspection of the mean scores for this variable revealed the children to be more accurate on the five-scheme (mean = 9.13°) than the four scheme (mean = 16.45°) task. As seen in Figure 3, the interaction effect was due to the fact that high M-processors displayed similar degrees of

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accuracy for both tasks. However, the low M-processors were more accurate on the five-scheme task (as determined by a Newman-Keuls range test), when it would be expected that greater accuracy would correspond to the four scheme task because it was developmentally appropriate.

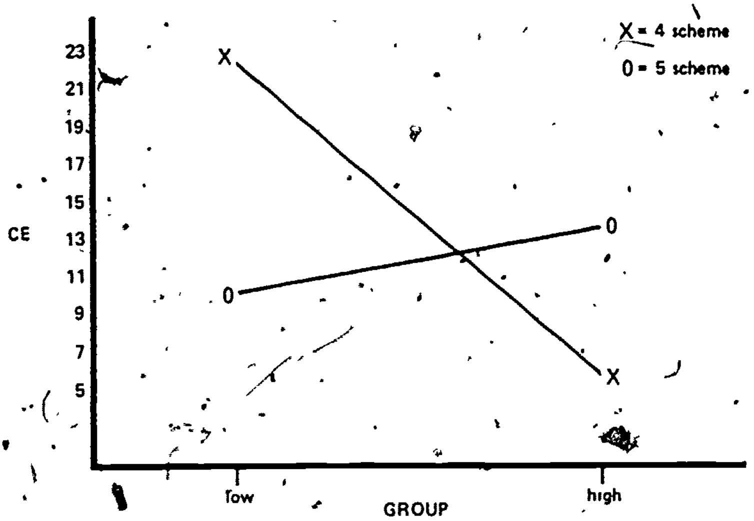

Fig. 3 Group x scheme interaction for constant error (all scores are negative)

Corresponding with the suggestions of Newell (1976) and Roy (1976), absolute error was analyzed as an additional measure of response accuracy to provide further evidence for children's skill acquisition and the child's capability to activate the appropriate schemes. A 2 x 2 (groups x schemes) factorial analysis of variance was performed on the absolute error scores for both the four- and five-scheme tasks. There was a significant main effect for groups, $F(1,18) = 9.58$, $p < .01$, with the high M-processors (mean = 18.63°) showing greater accuracy than the low M-processors (mean = 27.91°). The significant group x schemes interaction, $F(1,18) = 5.21$, $p < .05$, was similar to the same significant interaction for constant error. However, the absolute error interaction does show the important distinction (see Figure 4) that different interpretations of the performances were related to the particular dependent variables inspected, either absolute or constant error. In other words, the performance of the low M-processing group never exceeded the performance of the high M processing group on either task when absolute error was the dependent measure.

A Newman-Keuls range test on the interaction means showed that low M processors, as a group, were significantly less accurate on the four scheme task than on the five-scheme task, and also, that low M-processors were significantly less accurate than high M processors on the four-scheme and five-scheme tasks. There were no significant differences among the other three sets of means (low M-processors five-scheme task, high M processors four and five-scheme tasks).

Discussion

The hypotheses that both groups would produce a serial position effect related to motor recall on a developmentally appropriate task, and that high M processors would be more accurate and less variable than low M processors, were supported. While these findings were similar to those of Winsberg (1975), they were in contrast to results reported by Magill (1976)

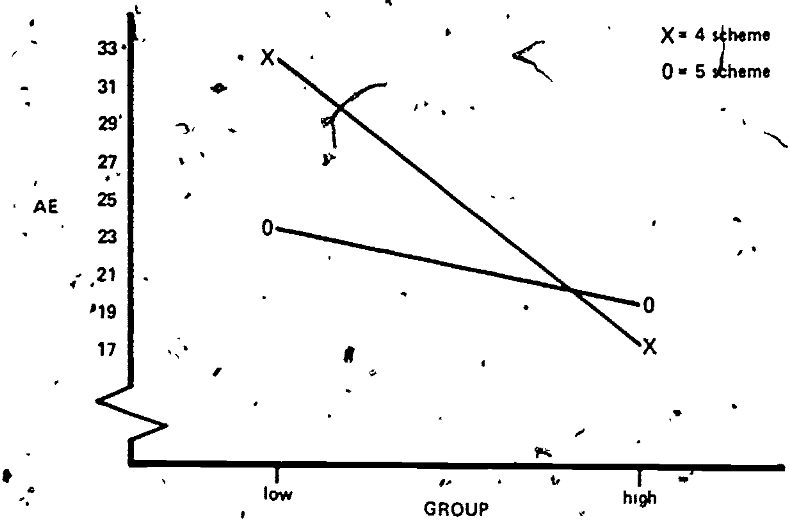

Fig. 4. Group x scheme interaction for absolute error

and Zaichkowsky (1974) Winsberg (1975) concluded that five motor responses would be sufficient to produce a serial learning effect The present study can be taken as partial support for this statement since five items did produce a slight recency effect for high M-processors. More pronounced was the effect on the four scheme task It is therefore suggested that four or five motor response items are sufficient to produce a serial position effect in children s motor learning but that the effect is greater when the task demands are developmentally appropriate for the subjects (in this case, e +4).

Results indicated that the final hypothesis was incorrect. No difference between groups in correct responses was found on the five-scheme task, probably because the task was beyond the developmental processing capabilities of the subjects High M-processors did perform significantly better on the four scheme task than did low M-processors. This was attributed to an unidentified cognitive strategy for the retention of task relevant cues developed by the high M group If early motor learning is composed of both verbal and motor components such that subjects will tend to convert a novel motor skill into a verbal problem to be solved (Adams, 1971), then the high M-processors were more efficient at encoding and decoding the appropriate cues Their ability to transform motor cues into more elaborate verbal-motor cues (schemes), and then to decode those schemes to produce efficient motor responses was evidenced by their superior performance scores at all three positions (see Figure 1).

It would seem that items presented early and late in a sequence should provide anchor points which allow a child to exert a modest amount of cognitive control over the motor response (Burwitz, 1974), if the response is developmentally appropriate. Middle-sequence items do not seem to serve this function, as is evidenced by the greater percentage of recall errors made on those responses in both motor and verbal learning investigations. A logical conclusion would be that it is the inability of a child to process serial information rapidly enough which results in the serial position effect

Another possible explanation is that the performance differences may be related to the greater ability of high M-processors to retrieve more accurately information from the long term store, as well as to retain information better in the short term store for subsequent recall. While low M-processors were also capable of employing these memory processes, they were less efficient than their high M counterparts The serial learning curves plotted in Figure 1 and, to some degree, those curves in Figure 2, correspond with Glanzer s (1972) interpretation that

early items are retrieved from long-term store, later items are retrieved from short term store, and middle items are retrieved with the largest amount of error because they are in a state of incomplete transfer between storage systems

Explanations of unexpected results, such as low M processors displaying better performance on the five-scheme task than on the four scheme task, are currently unavailable within a motor learning interpretation of neo-Piagetian theory The most plausible discussion would be to relate the findings to inconsistencies in the task analysis which is conducted on cognitive and motor tasks, as similar motor performance results to the present ones have been found elsewhere (Gerson & Thomas, 1977) Additionally, Thomas and Bender (1977) have reported that their motor performance data on correct responses did not equal the performance data on cognitive neo-Piagetian tasks (Case, 1972) There is obviously a need for closer scrutiny of neo-Piagetian theory before it is accepted as a completely viable explanation for children s motor learning

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